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THE WORK OF THE NORTH DAKOTA BIOLOGICAL STATION AT DEVIL'S LAKE

By Professor R. T. YOUNG

UNIVERSITY OF NORTH DAKOTA

DEVIL'S Lake, the euphonious substitution for the Indian Minnewaukon, or Spirit Water, is the name of one of the countless glacial lakes of northern North America. It is located in latitude 48, longitude 99, in North Dakota, at an altitude of 1,424 ft., in the upland prairie, which rises gradually from the Red River Valley to the high tableland, which sweeps westward through Montana to the Rocky Mountains.

It was formed by a morainic dam built by the ice across an old river valley, and originally drained southward through Stump Lake into the Sheyenne River (Fig. 1). At one time during the retreat of the continental ice sheet the glacial lake

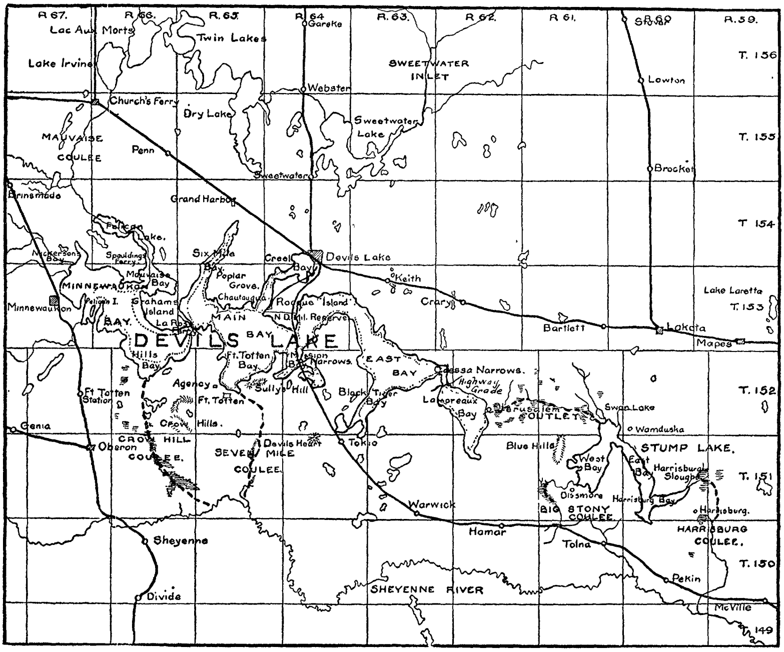

FIG. 1. MAP OF THE DEVIL'S-STUMP LAKE COMPLEX, showing the former connection of Devil's Lake with the Sheyenne River, via the Jerusalem outlet, Stump Lake and the Harrisburg Coulée. The full shore line is from the U. S. G. S. map of 1883. The dotted line shows the present shore line approximately. (From Simpson in N. D. G. S. Report for 1909–10.)

Souris, occupying a part of northern North Dakota and southern Manitoba west of the glacial lake Agassiz, found an outlet via the Mauvaise Coulée and the Devil's-Stump Lake basin into the Sheyenne River. With the disappearance of this lake the drainage area was restricted to about 3,500 square miles between Devil's Lake and the Turtle Mountains, a group of low morainic hills on the Canadian boundary.

With the retreat of the ice and consequent diminution of moisture, the evaporation of Devil's Lake came in time to exceed its supply, the connection with Stump Lake and the Sheyenne River was lost and its subsequent history has been in general one of gradual recession. Between 1885 and 1890, the connection with the Mauvaise Coulée was lost except during spring freshets, but the very heavy snowfall of 1916 has restored this.[1]

There is considerable reason to believe that the recession of the lake has not been constant, but that at least one period has intervened when it was much lower than at present, if not entirely absent. The evidence for this is the existence of an old forest in Stump Lake, from which the lake derives its name (Figs. 2 and 3); the presence of a submerged terrace (indicative of a former shore line) in Devil's Lake, similar to those

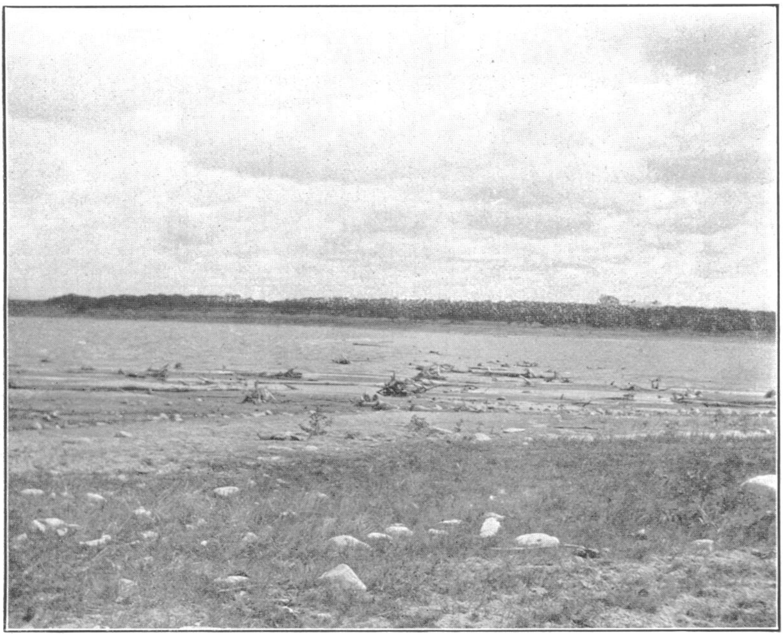

FIG. 2. STUMP LAKE, showing remains of submerged forest, from which the lake derives its name. (Simpson, photo.)

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[1] This coulée is again dry—1917.

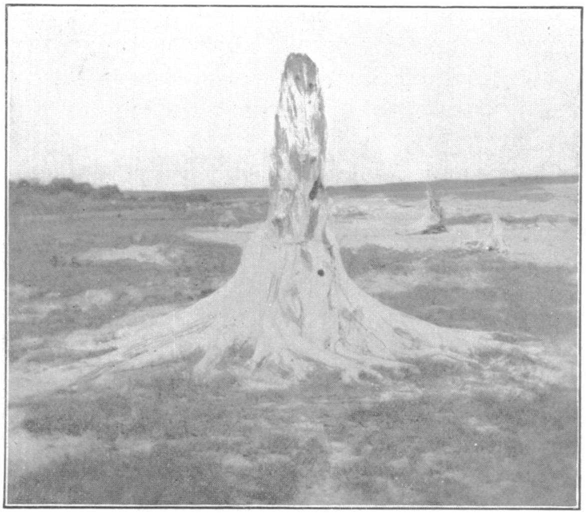

FIG. 3. ONE OF THE STUMPS OF THE SUBMERGED FOREST IN STUMP LAKE. (Simpson, photo.)

about its shores; and the existence of rock piles in the lake which were probably formed by ice action during periods of lower level (Fig. 4). With continued recession of the lake, many small ponds have been separated from the main body, and this process is still continuing. Three highway embank-

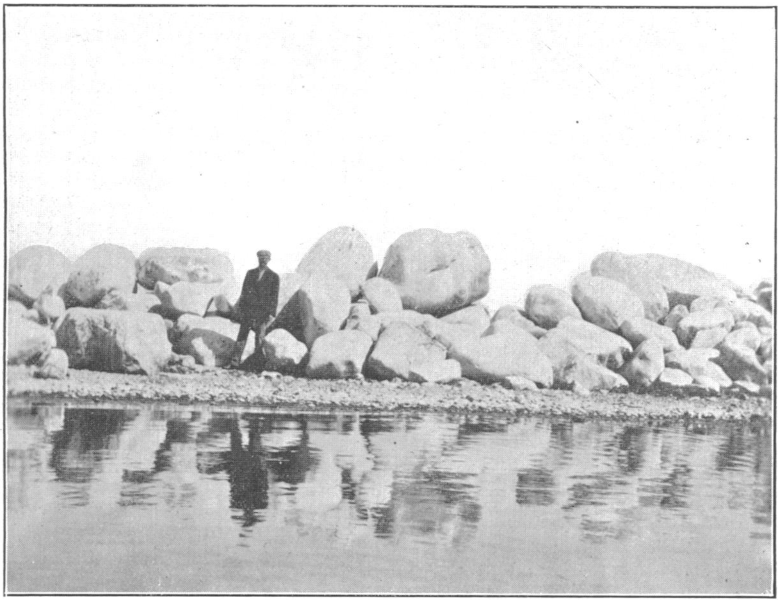

FIG. 4. ROCK PILE IN DEVIL'S LAKE. These glacial boulders have been piled up through ice action, and are evidence of a former lake level as low or lower than the present. (Simpson, photo.)

ments have recently been built across the lake, which together with its recession have divided it into four main parts. Taken as a whole the form of the lake is very irregular, several long arms extending out approximately at right angles to the central part.

The United States Geological Survey in 1883 estimated the area at 125 square miles, but its present area probably does not exceed 60 square miles. Its former maximum depth of 56 feet has now been reduced to 18 feet.

The recession of the lake has left its evidence upon its former shores in the form of terraces indicating the old beach lines. Two of these are easily traceable, and many smaller and less distinct may be found (Figs. 5 and 6).

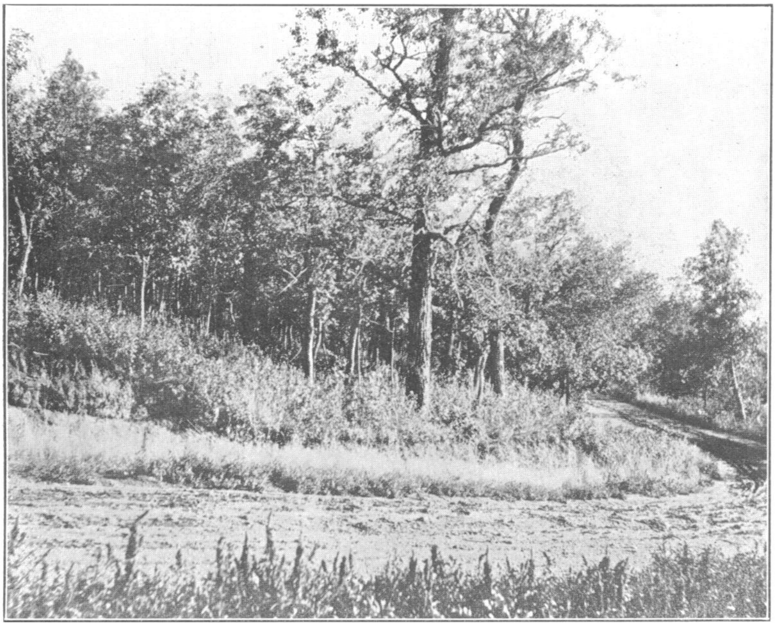

FIG. 5. THE "A" BEACH, THE HIGHEST LEVEL OF DEVIL'S LAKE. The highway is cut through the bank at the left. The water came to the foot of this bank. (From Simpson, N. D. G. S. Report for 1909-10.)

The climate of the region in which Devil's Lake lies is characteristic of inland plateaus. The precipitation averages 18 inches. The winters are long and cold, with a minimum temperature of —44° F.; the summers short, with generally cool nights and warm days, the thermometer occasionally reaching 100° F. in the shade. Many cool days occur in summer, however, frost in June and August, while unusual, being by no means unknown. Devil's Lake is ice-bound from the middle of

November to the middle of April, the ice commonly reaching a thickness of three feet. After breaking in the spring it is driven about the lake with great force by the high winds characteristic of the region, which occasionally reach a velocity of sixty miles an hour, and it is through this ice action in considerable measure that the rock "piles" are formed.

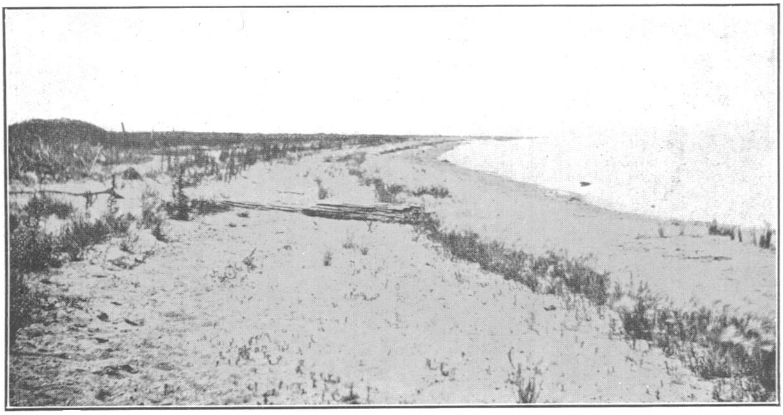

FIG. 6. THE SHORE OF DEVIL'S LAKE, showing recent beach lines (indicated by the zones of plant growth), and a sand spit formed by recession of the lake level. (Young, photo.)

As a result of the recession of the lake a great concentration in its salt content is occurring. The present amount of total solids is about 15,000 parts per million, consisting largely of the sulphates of sodium and magnesium, and sodium chloride. The specific gravity is 1.014 and the osmotic pressure 6.5 atmospheres.[2] These figures vary somewhat from time to time dependent on the lake level. In spite of its alkaline character the water is drunk to some extent by cattle. The chemical character of the various parts into which the lake is divided varies widely, dependent upon different factors, such as date of separation from the main body, character of shores with consequent amount of run off, and depth.

To the physiographer Devil's Lake is of great interest, showing as it does so clearly the evidence of its past history, with the same processes in action at present; but to the biologist it is of even greater interest by reason of the changes in its inhabitants, which are accompanying the changes in its physical and chemical condition.

Previous to 1883 the lake swarmed with pickerel, but shortly subsequent to that date and coincident with a rapid decrease in the lake level, they suddenly disappeared.

[2] These data refer to the main part of Devil's Lake.

In order to ascertain, if possible, the cause of their disappearance, to investigate the possibility of restocking the lake with fish and to study the many problems of scientific interest presented by it as well as by other waters in the state, the legislature of 1909 made an appropriation of $5,000 for the construction of a building, beside $3,000 annually for maintenance.

The building (Fig. 7) is a tasteful two-story structure, the lower story being constructed of boulders from the lake shore and the upper of frame covered with stucco. It contains a small hatchery equipped for handling several million eggs at one time, a small museum of local animals, a large assembly room, five rooms for private workers, beside a director's office, and a chemical laboratory.

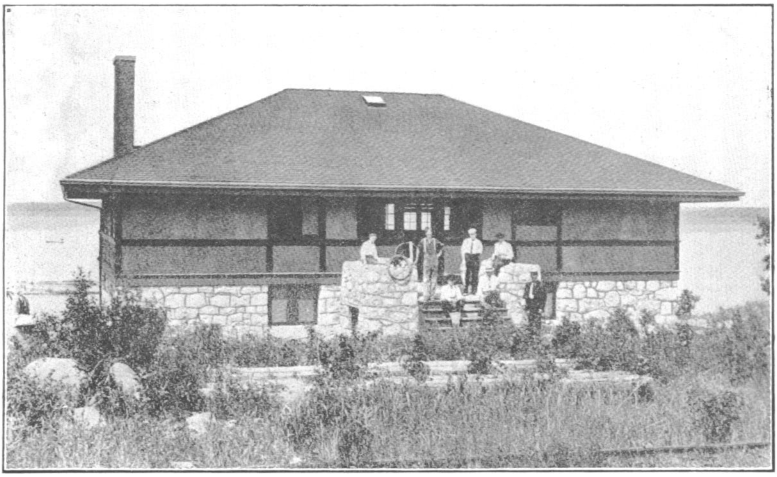

FIG. 7. NORTH DAKOTA BIOLOGICAL STATION AT DEVIL'S LAKE. (From Brannon, Report of the Biological Station for 1909–10.)

The equipment, while simple, is adequate for the purposes for which it is designed.

The investigations of the station have covered three main lines—experiments in restocking the lake with fish, studies on the effects of environment and isolation on Crustacea and studies of the plankton and its environment.

For a number of years sporadic attempts at stocking the lake have been made by residents of the vicinity, and in 1907 the U. S. Bureau of Fisheries sent a field party to study the lake and report upon the feasibility of planting fish in it. They found that several species of fish could live in the lake for a number of weeks.[3]

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[3] See Pope, T. E. B., "Devil's Lake, North Dakota." Bur. of Fish, Doc. 634, 1907.

Since the establishment of the station experiments in restocking have been carried on by the former director, Dr. M. A. Brannon and by the writer.

These experiments have shown that when conditions are favorable—if the fish are in good condition on arrival and the water is cool (less than 65° F.), it is possible to introduce them directly into lake water with very little loss. On the contrary, when the fish suffer from high temperature or insufficient oxygen in transit, and reach the lake in poor condition better results are obtained by holding them for several days in concrete tanks, where they are gradually acclimatized to the lake water. This method also appears to be safer for the very young fish (six to eight weeks old), while older fish (one year or more) will bear direct transfer if conditions are favorable.

Beside the experiments with fingerlings and older fish, a large number of the pike perch and yellow perch have been hatched and transferred to the lake. While under observation in the hatchery jars or troughs, a large percentage of the eggs hatch nicely and the young fish are active and appear perfectly healthy. Owing to difficulties in keeping these very small fish in aquaria or cages it has not yet been possible to hold them for observation for any considerable time after hatching, but it is probable that some means may be devised for doing this in future. The experiments have been conducted mainly with yellow perch, both because of its ability to live in the lake and the available supply; but it has been found that other species (catfish, black bass, rainbow and steel head trout and pike perch) will under favorable conditions live in the lake.

These experiments are of great interest in their bearing on the ability of fish to withstand changes in the density of water.

The problem of the transfer of organisms between media of different densities opens up a wide field of investigation and has led to much experiment thus far and to many conflicting results. What are the factors involved in such transfer? Is it purely a question of osmotic pressure, or of chemical action between the body fluids and the surrounding media? What is the rôle of salts in the preservation of life? Do they act upon the organism independently of each other or is there a combined effect? Is it possible to accustom all organisms to changes in density of their surrounding media, or are some of them closely circumscribed in this respect, and what are the limits of such adaptability? If differences in this respect exist in different organisms, to what are they due? What is the relative effect of sudden and gradual changes in density? These are some of the many questions involved in this problem.

The experiments at Devil's Lake have shown clearly that many species of fish can withstand changes in density of about .011, that the ability of the fish to withstand such changes is largely dependent on the temperature and on the condition of the fish at the time, and that marked differences exist between individual fish in this respect.

The reasons for the disappearance of the pickerel can not be stated with certainty. Coincident with their disappearance a marked decrease in lake level took place. This cut off the coulée coming in from the lakes northward in which the pickerel bred. Previous to their disappearance they were taken from the lake in large numbers without restriction, and this fact coupled with the loss of their breeding grounds is sufficient in some measure to explain their disappearance. It does not, however, explain the suddenness of their disappearance, which, according to all reports, took place between 1885 and 1889. It is probable, therefore, that some epidemic was the third factor in their reduction. Regarding this it is of course impossible to obtain definite information now.

A second line of work conducted by the station is the study of the variation produced in organisms by changes in the physico-chemical character of their environment and by isolation, using for this purpose mainly the copepod *Diaptomus* (Fig. 8).

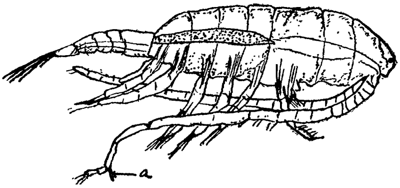

FIG. 8. *Diaptomus* (MALE) SHOWING PROCESS, *a*, OF THE RIGHT ANTENNA. The length of this process, together with that of the antenna and the body, shows marked differences in inhabitants of different ponds, as the result of differences in environment and of isolation. Magnified 50 diameters. (Moberg, del.)

A large number of these from ten of the separate parts of the lake collected in all seasons of the year have been carefully measured and compared. The following data have been chosen for such comparison: length of body, antennæ and process of right antenna in the male.

This study has shown clearly a distinct variation in all of these dimensions as the result of such changes in environment, the length of the process of the antenna of the male varying directly, while the length of the antenna varies inversely as the length of body.

These results are consistent with those of many other workers respecting the influence of environment and isolation in modifying organisms. They open up a wide field of further observation and experiment, such as the transfer of organisms from one pond to another to determine whether the differences are constant or reversible; the gradual increase in density of the water to determine how soon such increase shows its effect, and whether it has any other effects in influencing the sex and number of offspring in successive generations, etc.; a comparison of the differences found between organisms in lakes far distant and those in the Devil's Lake complex; a study of the developing organisms in the various ponds to determine whether the larvæ show differences comparable with those of the adults; these are some of the many interesting and important problems waiting to be solved. Such questions, while seemingly of interest only to the specialist, are nevertheless of profound importance to all of us, for they seek to answer in some measure the ever-vexing question of "nature vs. nurture." If it is reasonable to believe that all protoplasm is fundamentally alike, however widely it may differ in its manifold forms and reactions, then the solution of this question of the relative part played by heredity and environment in the development of even so humble a creature as a little shrimp-like animal about one twentieth of an inch in length, should aid in answering the same question in human development. The fact that in the Devil's Lake complex we have in many cases an exact, and in all a fairly accurate record of the time that nature has been performing these isolation experiments for us, and that we have ready made, as it were, a large number of experimental ponds in which to conduct further experiments of our own, renders this region an unusually favorable one in which to study the problem.

The plankton, the minute free-swimming organisms, in the lake has been extensively studied in its relation to its environment. These studies comprise over 800 collections from all parts of the main body of the lake and several of the outlying ponds. These have been taken both by day and by night, at all times of year, including midwinter. The organisms contained in these collections are now being counted, after which a comprehensive report will be prepared. Coincident with many of these collections determinations of temperature, dissolved gases, etc., have been made. Studies of the plankton have brought out clearly the interesting fact that these minute organisms frequently occur in swarms, the causes of which are not at present clear. In two regions separated by only a few feet may occur immense numbers, especially of the cladoceran Moina, while the intervening areas may be comparatively free from it. Differences as great as 400 per cent. may occur between two places seemingly alike in every respect. So far as can be determined, there is no difference either in chemistry, physics or food supply to determine these differences. Their explanation must therefore be sought in some as yet obscure biological factor.

Some preliminary studies have also been made of the Red and Missouri rivers and of other waters in North Dakota, but the main activities of the station have been confined to Devil's Lake and its adjacent waters.

The fauna and flora of the lake are interesting both in respect to what they do, and do not contain. The only vertebrate inhabitants are the stickleback, the leopard frog and the salamander *Amblystoma.* Among the invertebrates the crustaceans, insects and rotifers are each represented by several species. One of the latter *Brachionus,* named from its habitat *satanicus* by Mr. Rousselet of London, is new to science. A few extinct mollusks occur and at least one arachnid, but the cœlenterates, sponges, polyzoans and annelids are apparently entirely absent, and thus far but one free-living flatworm has been found. Nematodes on the contrary are common, and include several species as yet only partially determined. The animal phylum most largely represented is the protozoa. These include chiefly ciliates and flagellates, many of which are as yet indeterminate and probably represent new species. The rhizopods are poorly represented, *Arcella vulgaris* being the only one which occurs at all commonly. This is the more remarkable in view of the fine layer of ooze covering the lake floor. The fact that this layer is occasionally lacking in free oxygen may explain their absence, but Juday's observations[4] on animals living in water lacking free oxygen, and the presence of several other protozoa in the ooze in Devil's Lake, render this explanation somewhat questionable. One of the commonest animals in the lake, the midge *Chironomus,* occurs as a larva exclusively in this ooze.

The ditch grass (*Ruppia*) grows abundantly in the shallower parts of the lake, forming a tangled mass, which in some places prevents navigation with power boats. There are many species of unicellular algæ; some of which, especially the blue-greens, are very abundant. It is difficult to assign to any one group of plants the most important part in the life of the lake, although the diatoms with some fifty species take first place in respect to variety and play a very important part as food for the animals.

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[4] Juday, C., "Some Aquatic Animals that Live under Anærobic Conditions," *Trans. Wis. Acad. Sci.,* XVI., p. 11.

The busiest part of the lake, biologically speaking, is the *Ruppia* zone which occurs in depths of from two to five feet. Here is the nesting place of the stickleback. Attached to the *Ruppia* are masses of the filamentous green alga *Cladophora,* while to this again are attached numerous sessile diatoms and protozoans. Many free-swimming protozoans, rotifers, nemaodes and copepods also occur here; some by chance as they are driven hither and yon by the currents in the lake, others finding favorable shelter in the tangled mass of *Ruppia* and *Cladophora,* and seldom occurring elsewhere.

The rocky islands are the breeding homes of cormorants, ducks and terns, while many other species of water fowl breed abundantly in the marshes, which in some places occupy the old lake bottom. The cormorant colony on "Bird Island," as it is known, is one of the most interesting places about the lake

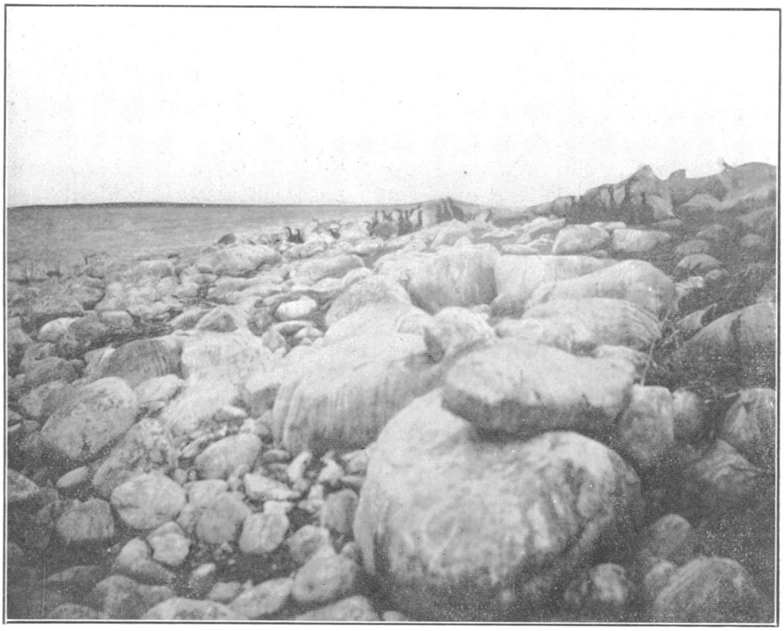

FIG. 9. BIRD ISLAND IN DEVIL'S LAKE, the home of the double-crested cormorant, whose nests may be seen among the rocks. (Young, photo.)

(Fig. 9). On the approach of the intruder the old birds, and such of the young as are able, scramble off into the water, while the birds which are too young to leave the nest voice their protests in inarticulate squawking, at the same time disgorging masses of sticklebacks and young salamanders, which form their staple diet. The nests, rude piles of sticks, are crowded together among the rocks. After the breeding season gulls, ducks and terns gather in flocks about the lake, and together with migrant phalarope and sandpipers form a busy and restless population. Some of the flocks of ducks are so large that as they take wing they make a sound like rushing water.

On the southern shore is a long low ridge of morainic hills, the highest point of which is named "Sully's Hill" after General Sully, the old Indian fighter (Fig. 10). The major part of this hill which is some three miles long has been set aside as a national park and fenced in for the retention of wild animals (elk, deer, bear, etc.) with which it is planned to stock it.

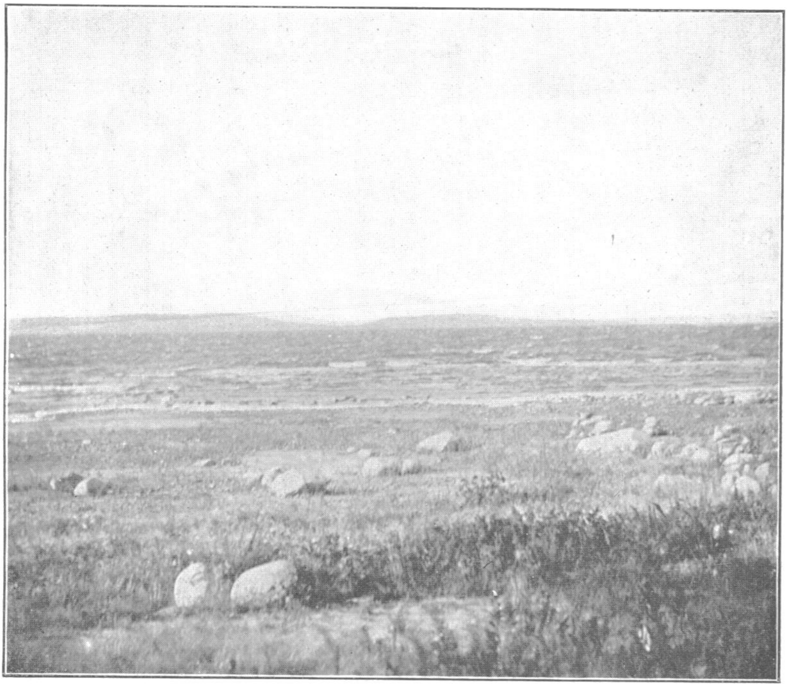

FIG. 10. DEVIL'S LAKE, shore strewn with glacial boulders in fore-ground. Sully's Hill National Park site in back-ground. (Young, photo.)

About two miles to the west of Sully's Hill is the old frontier Fort Totten, now used as an Indian school, while in wretched "shacks" scattered over the hills on the reservation still live some of the old warriors, who in days gone by hunted the buffalo and the white man over the vast plains of the Dakotas.